DAIMLER

SUPERTRUCK

Improving Transportation Efficiency Through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck II

Justin Yee, Principal Investigator, Vehicle
Jeff Girbach, Principal Investigator, Powertrain
June 21, 2018

Daimler Trucks

Project ID: ACS100

FREIGHTLINER FUSO WESTERN STAR Thomas BUILT BUSES BHARATBENZ

Overview

Timeline

Start: January 1, 2017

End: December 31, 2021

PH1	PH2	PH3	PH4	PH5

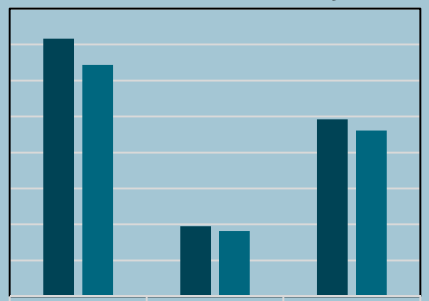
Status 6/2018 = 30% Complete

Budget

Project Total $40Mil

DOE Share	$	20,000,000
Michelin	$	1,000,000
ORNL	$	500,000
NREL	$	203,254
Detroit Share	$	12,468,918
DTNA Share	$	5,827,829

2017 Summary



	Total	DTNA	Detroit
2017 Planned	7,163,449	1,948,794	4,916,655
2017 Actual	6,429,233	1,819,658	4,609,575

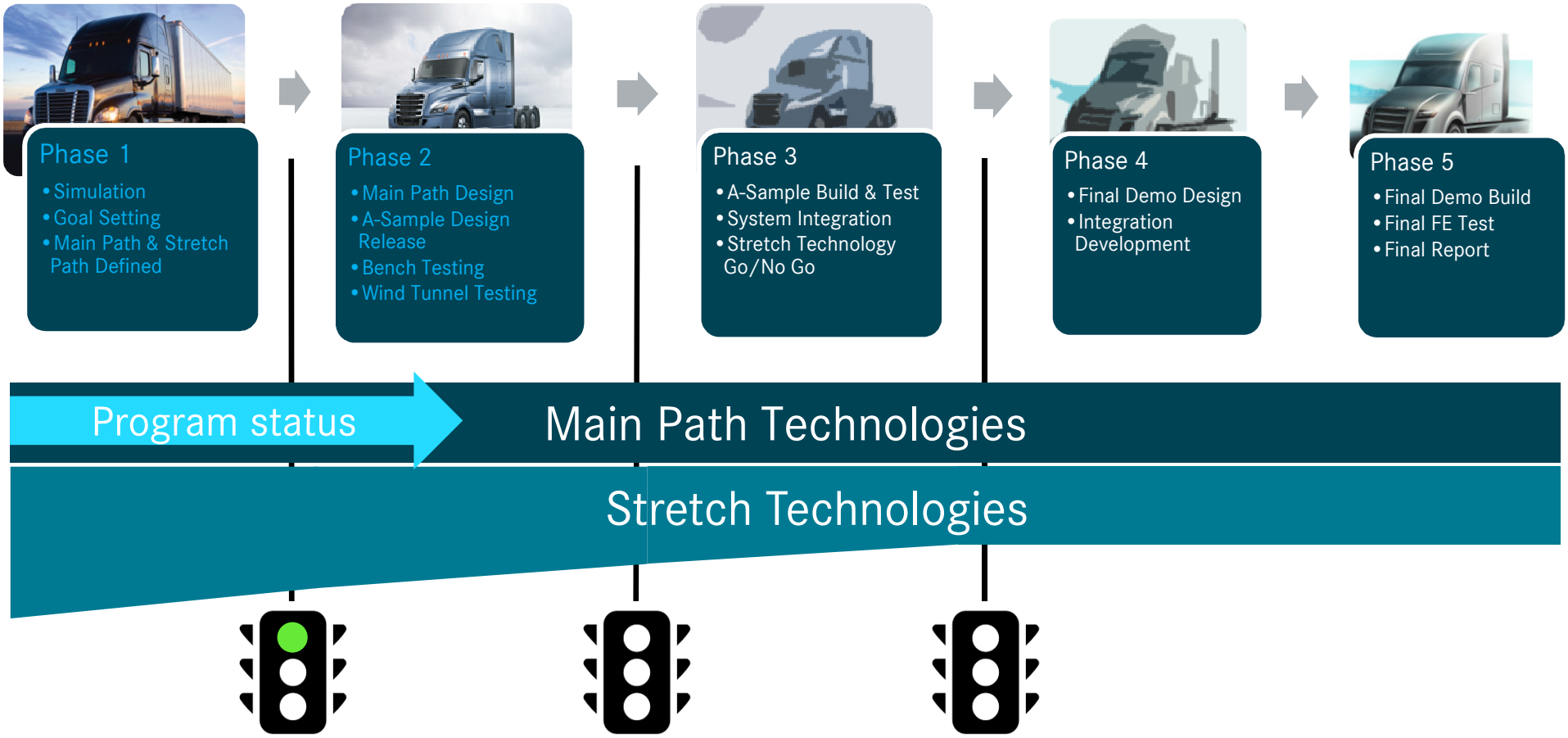
Barriers

- Many of the technologies (e.g. Aero – Cooling - 48V) are very much interlinked, so as one part of the vehicle matures and changes, we must recheck the interaction to the other technologies.
- Basic aero shape development is done, exterior design can now begin.

Project Partners

- Schneider National
- Strick Trailer
- Michelin
- Oak Ridge National Labs
- National Research Energy Laboratory
- University of Michigan
- Clemson University

Objectives – Project Phases

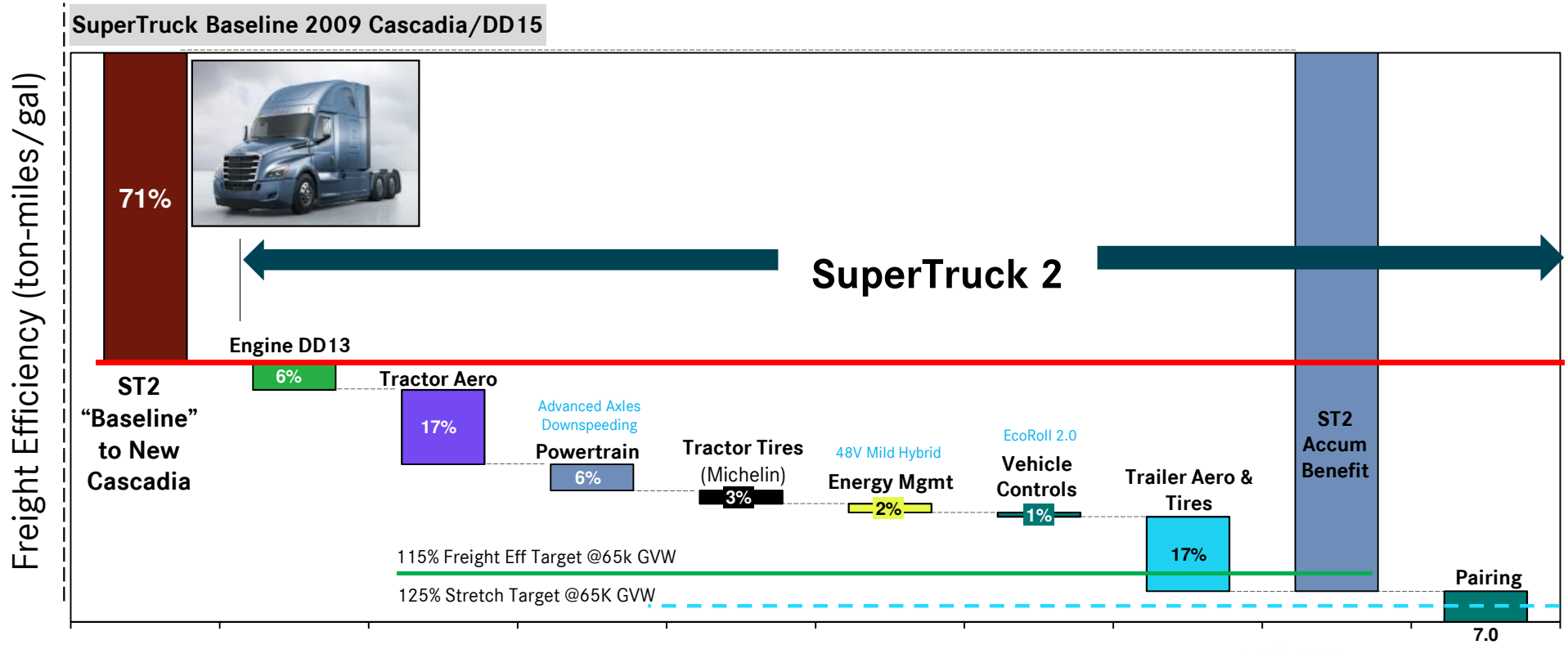


Phase 2	Aero Tinker Truck Assembled	100% complete	April 2018
	A-Sample Engine Delivered to DTNA	75% complete	Sept 2018
	A-Sample Design Release	50% complete	Dec 2018

Approach – SuperTruck 2 Roadmap to Success

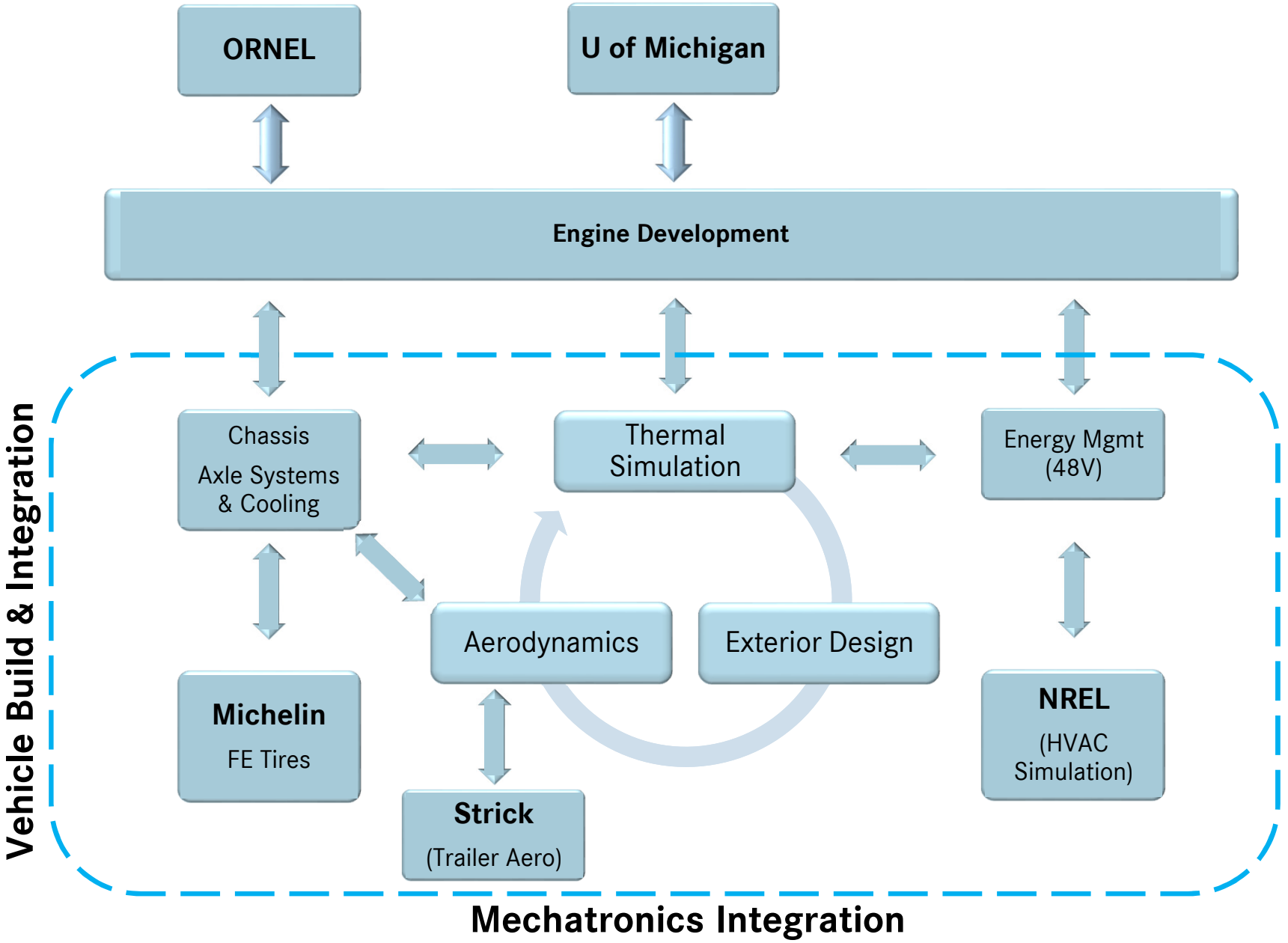
On Road (Portland-Pendleton) validation to determine starting point between SuperTruck "baseline" to New Cascadia @65k lbs combined gross vehicle weight

Simulation used to determine ST2 workstream goals



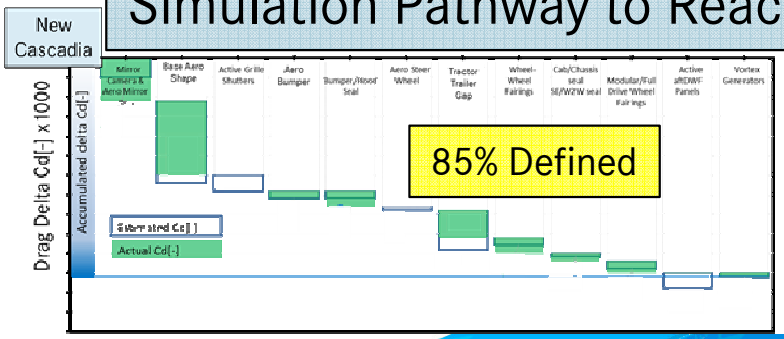
Plan: Build off of our 2017 New Cascadia to reach 115% (+) freight efficiency improvement

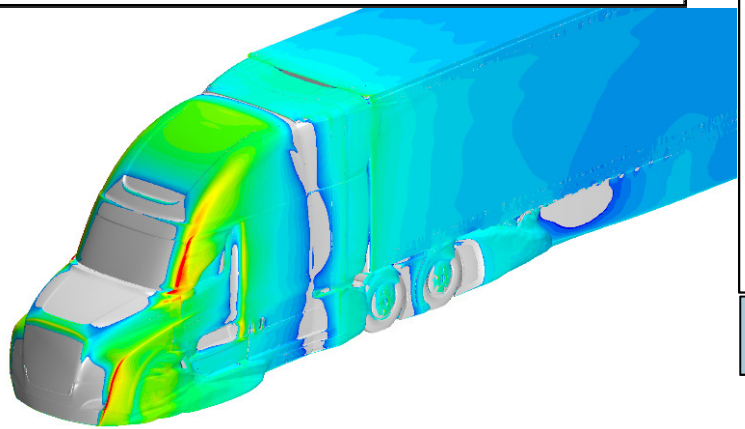
Collaboration Model

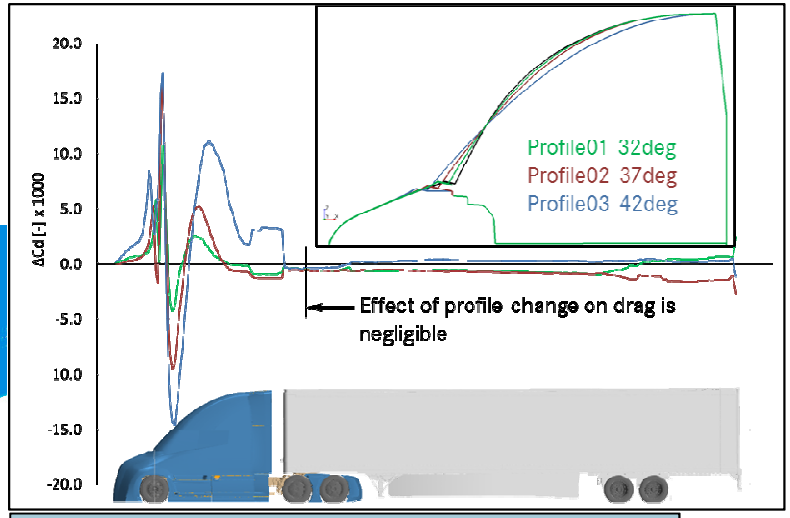


Technical – Aerodynamic & Exterior Development

Simulation Pathway to Reach Aerodynamic Target



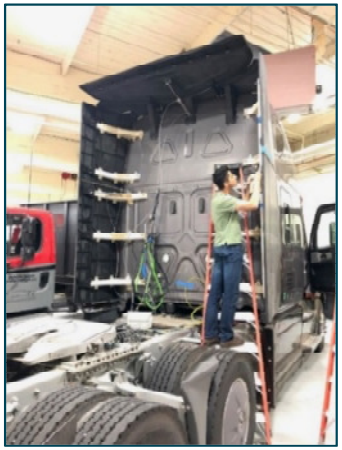




Example: Windshield Angle Study

Aero Tinker Truck: Investigation of Tractor-Trailer Gap

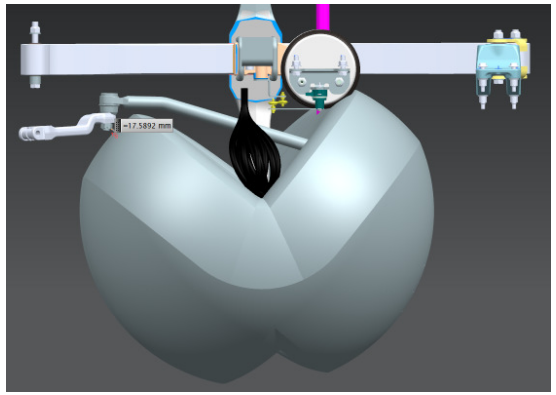
5/2018 - On road validation of concept



Technical – Chassis Developments

Tire Study – Michelin

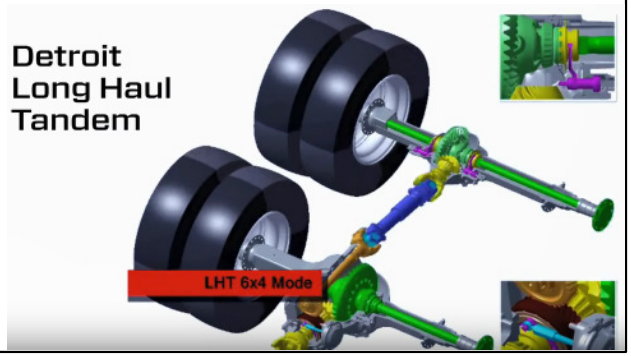
Investigation of P315 Tire Width (similar size to European Union specifications



Interference with Front Suspension Decision to move forward with P275 width

Michelin tire will be optimized for clutched rear axle – “Detroit Long Haul Tandem”

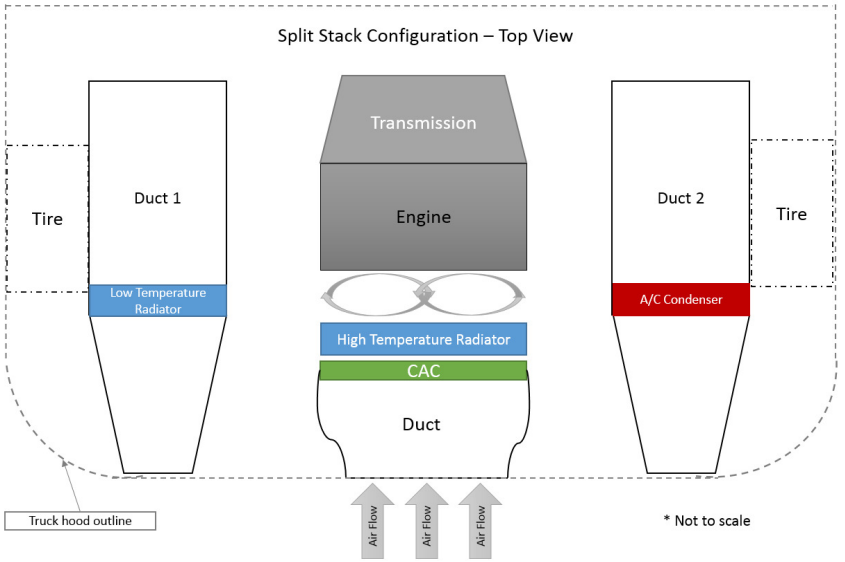
Operates like a 6x2 at hwy speeds



Thermal Investigation

New cooling configurations:

- Looking for ways to separate the cooling circuits in order to optimize the performance of the different cooling systems
- Use lessons learned from SuperTruck 1 cooling layout.

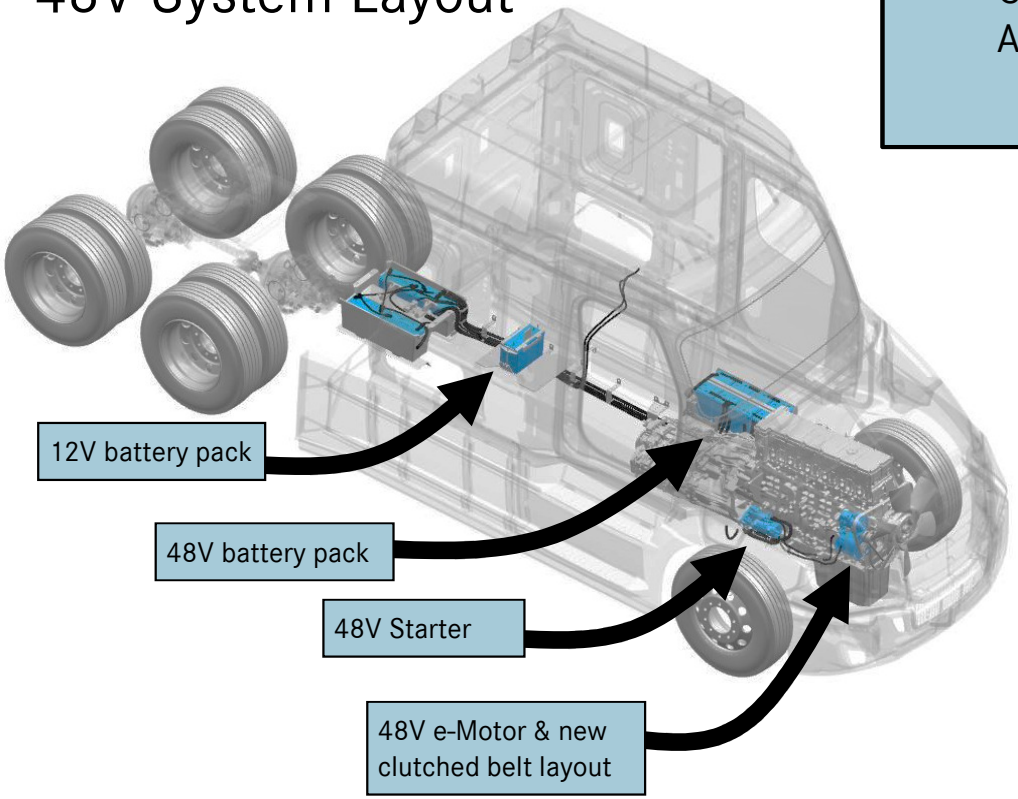


Technical – 48V Investigations

Replaces existing alternator with 48V motor generator:

Pull power off the engine in place of the alternator.
Consume battery power as an e-motor to assist powertrain.
Allows for energy recovery “mild hybrid”.

48V System Layout



Overview of 48V potential benefits:

- **Mild Hybrid** **FE↑**
- **Eco-Roll 2.0 Support** **FE↑**
- **Efficient Electrical Generation** **FE↑**
- **Reduced Air Compressor Drag** **FE↑**
- **Engine off HVAC** **FE↑**
- **Pumps & Fans for Cooling System**

Freight Efficiency Potential = 4%

Summary of Technical Investigations

Blue Items in Active Simulation or Design Phase

	Main Path	Stretch Items	Investigation Topics
 Aero	• Aero front • Improved tractor-trailer gap mgmt • Improved wheel treatments • Aero windshield • Mirror cameras • Improved aero seals	• Under hood airflow • Aero Chassis fairings • Low cost aero trailer treatments	• Aero Door • Cab to chassis sealing
 Engine	• Down-sped, high BMEP DD13 engine • High peak firing pressure • Heat loss & friction reduction measures • Modified air system layout	• In-cylinder thermal barrier coatings • Additional WHR heat sources • Active drivetrain fluid temperature control • Real-time predictive powertrain control	• Electrification of powertrain accessories • Additional parasitic losses reduction measures • Unconventional combustion regimes
 Chassis & Powertrain	• High FE Tires (Michelin) • New Radiator Configuration • Advanced Axle System	• Axle temp monitoring • High FE gear oil	• AC Condenser w/electric fan
 Energy Management	• 48 Volt system • Improved pHVAC system (NREL)	• Start/Stop System • Controlled load management • Reduced solar absorbance paint	• Energy recuperation • Solar energy
 Vehicle Controls	• V2V communication • Eco Roll 2.0 • Mechatronics System Integration	• Intelligent Controls • HMI for new systems	

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SUPERTRUCK

SuperTruck 2 Powertrain

Jeff Girbach, Principal Investigator, Powertrain

June 21, 2018

Daimler Trucks

Project ID: ACS100

FREIGHTLINER

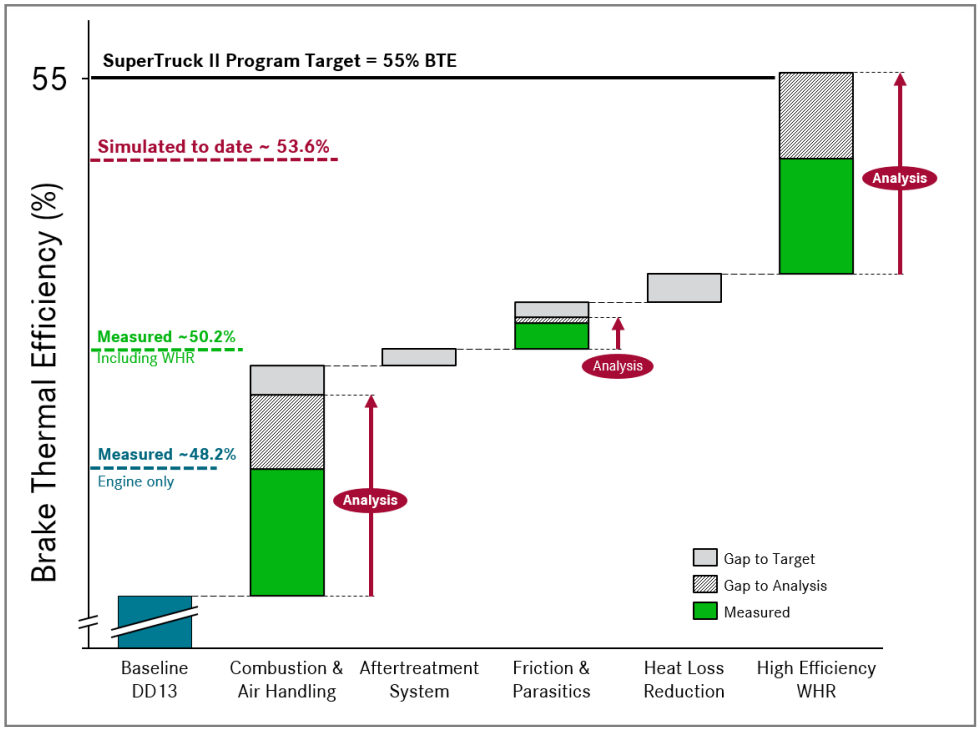
FUSO

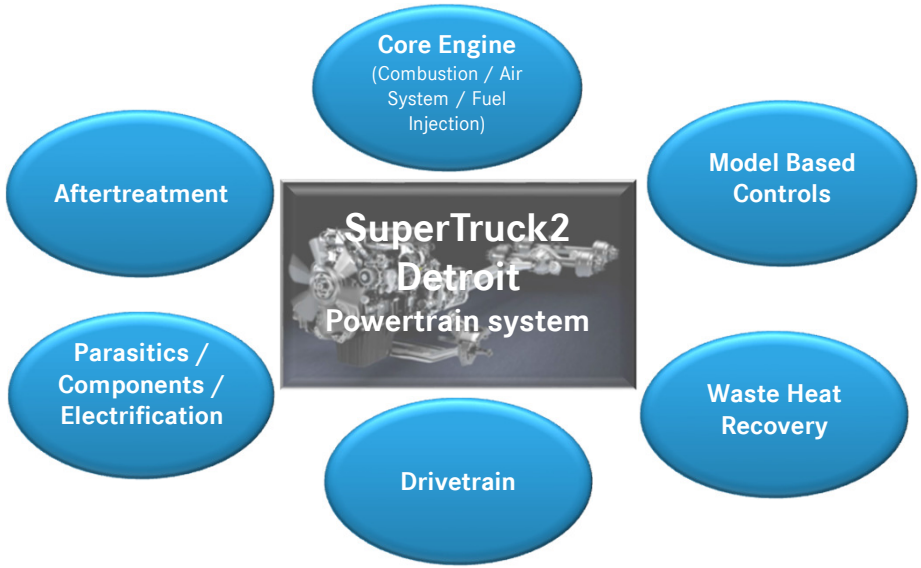
WESTERN STAR

Thomas BUILT BUSES

BHARATBENZ

Approach – Powertrain Research Components

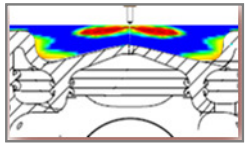


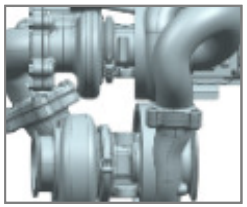


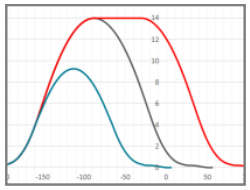
- Powertrain systems designed for further engine downspeeding
- High BMEP DD13 Engine
- Higher peak firing pressure / Lower heat loss / Higher cycle efficiency
- Significant focus on parasitic loss reduction
- Predictive powertrain controls for real-time setpoint optimization
- Investigation of high risk technologies for higher efficiency

Technical – Powertrain Developments

- **Designed, modeled and evaluated a number of fuel economy improvement measures**
- **Leveraging ORNL & U. of Michigan's capabilities in the areas of combustion CFD & Model Predictive Controls**
- **Started the procurement phase for selected components**
- **Powertrain system integration in A-Sample vehicle for Q4 2018**





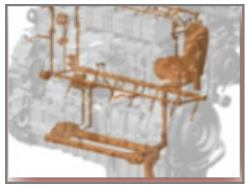


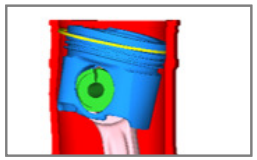
Downspeeding enablers
- Two stage turbocharging
- Interstage cooling
- High hydraulic flow injectors

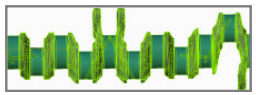
Faster combustion enablers
- High compression ratio
- Higher peak cylinder pressure
- Redesigned bowl shape
- Thermal barrier coating

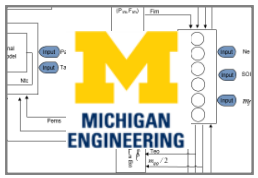
Air system
- Miller cycle valve timing
- Long loop EGR
- Two stage EGR cooling

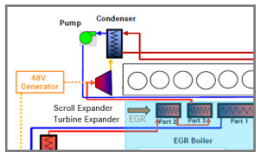
Controls
- Model predictive controls
- Transient calibration optimization

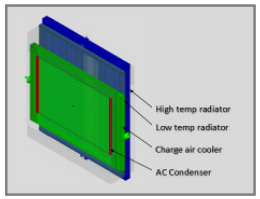












Parasitic Losses Reduction
- Oil flow reduction
- Low viscosity oil
- Higher oil temperature
- Active piston cooling jets
- Liner surface conditioning
- Variable speed water pump

Waste Heat Recovery
- Low temp. WHR condensing

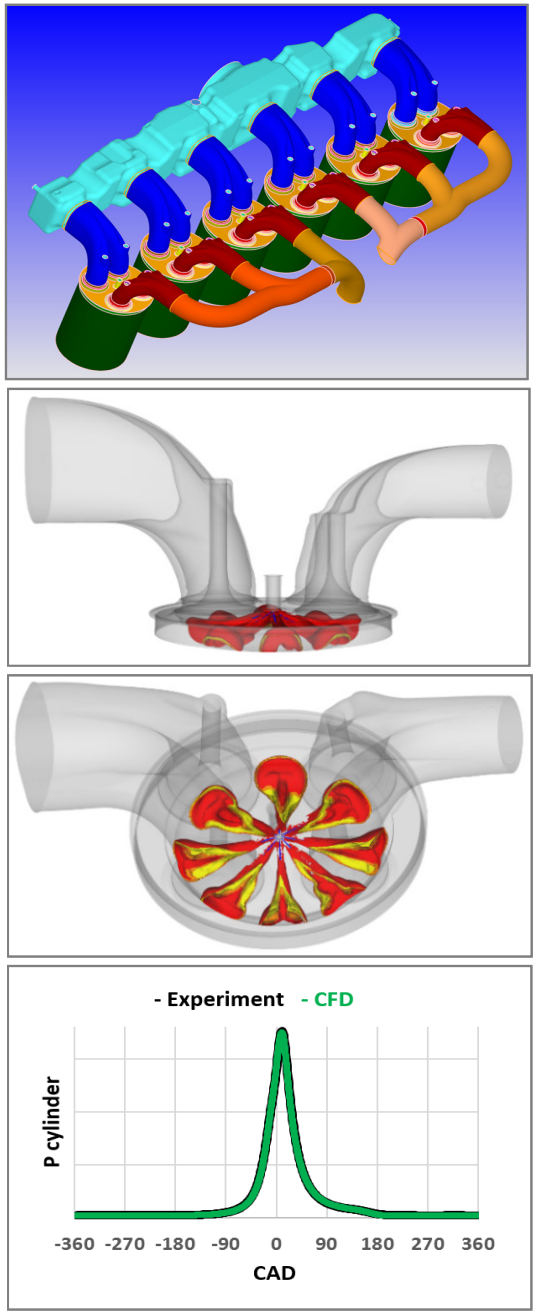
Aftertreatment
- Close-coupled SCR

Fluid Temperature Management
- Split Cooling System
- Transmission temp. management

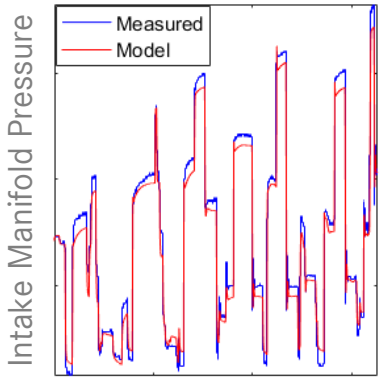
Technical – Combustion CFD

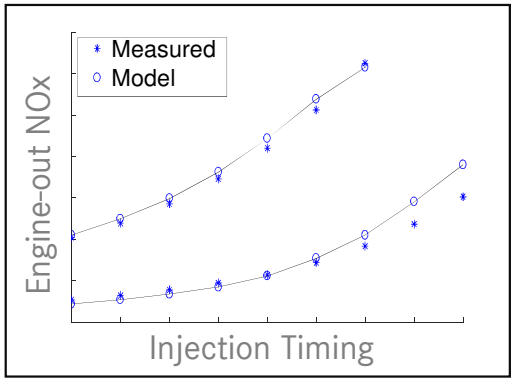
OAK RIDGE National Laboratory | NATIONAL TRANSPORTATION RESEARCH CENTER

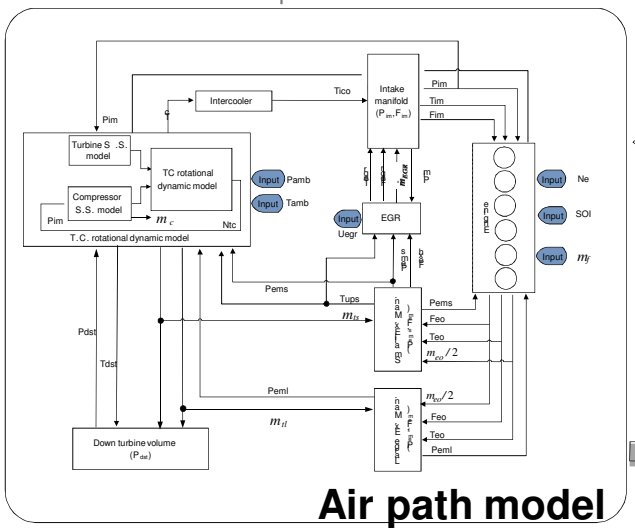
- Partnering with Oak Ridge National Laboratory for evaluation of advanced powertrain components and strategies
- Computational evaluation of efficiency improvement strategies
- Single- and multi-cylinder configurations
- Developing conjugate heat transfer (CHT) model of engine
- Piston, liner, head, coolant jacket and passages
- Study will investigate potential impacts of thermal barrier coatings on cylinder temperatures and combustion performance



Technical – Modeling Predictive Engine Controls



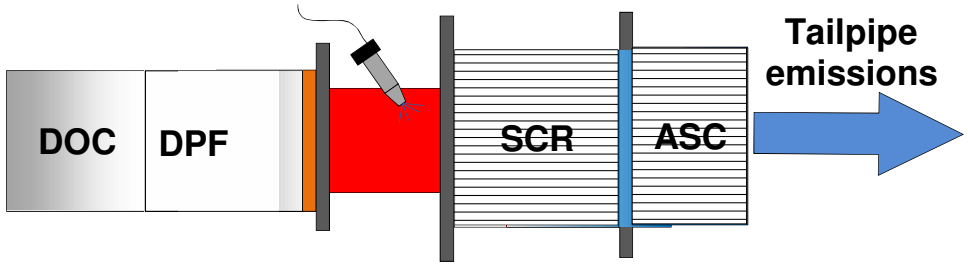




Cycle resolved NOx model

NOx

Flow, Temperature



Thermal model

Thermal + Chemical Kinetics models

Objectives

- Develop physics-based models of the engine & aftertreatment systems for use in SuperTruck2's model predictive control algorithm
- Build on the success of ST1's model-based control algorithms
- Improve transient engine performance & emissions

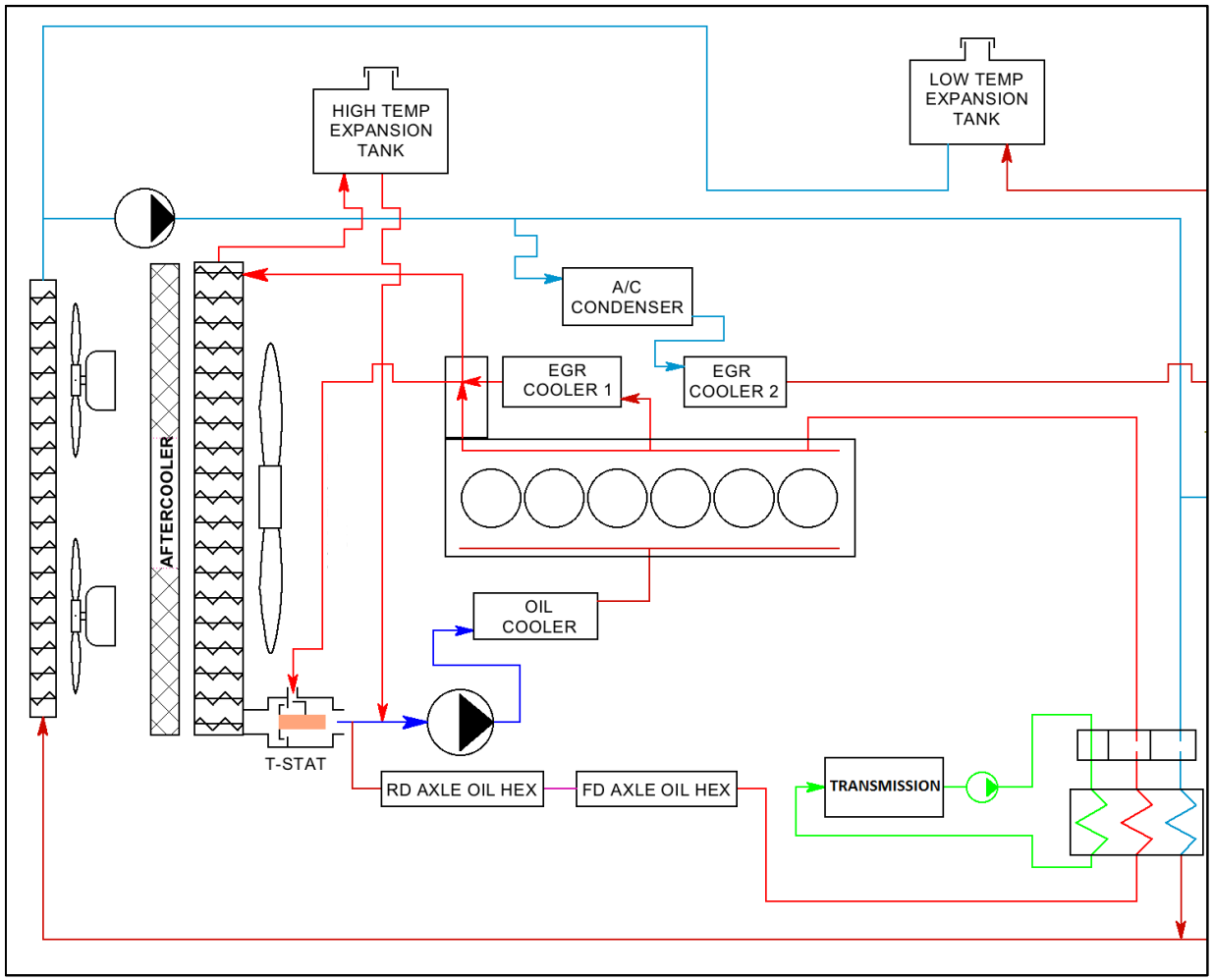
Status

- Engine systems well characterized
- Focus now on aftertreatment system

Powertrain Control Laboratory

MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

Technical – Split Cooling System



Description

- Cooling circuit is split into hot and cold loops
- Cold water is used to reduce CAC/EGR outlet temperatures
- Significant impact on front grille/hood/ cooling fan design

Status

- Detailed system simulation completed
- Radiator sizing on-going

Remaining Challenges & Barriers

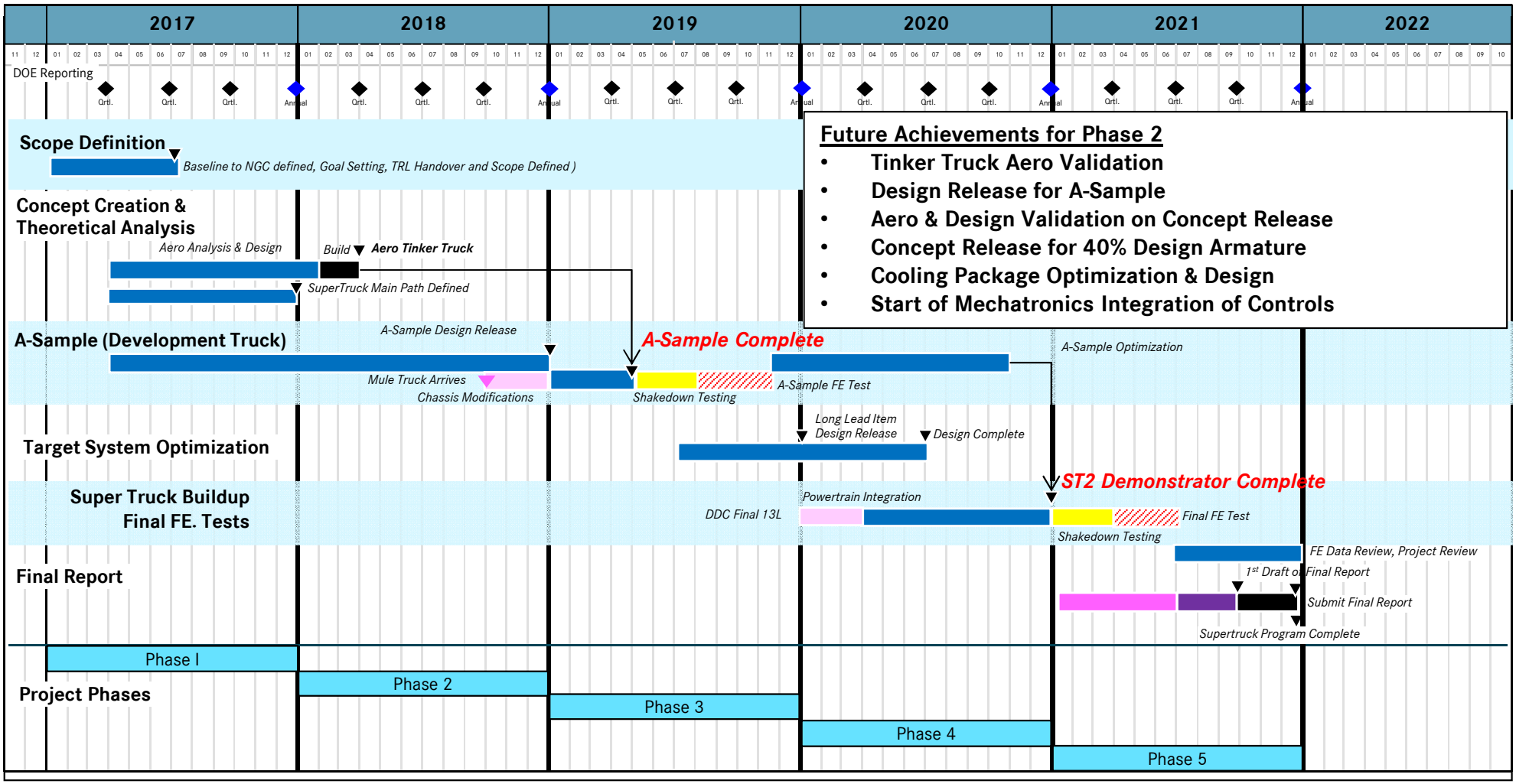
Technical

- Optimization of the cooling system is starting . This is needed to determine the grille openings and lock down the exterior design before starting the 40% clay model.
- CFD validation of the ST2 exterior concept is not yet finalized. There is a risk of not achieving the expected results gleaned from independent studies in the combined shape.
- WHR System currently in test shows a fuel efficiency performance that is insufficient to justify added cost/complexity. The Detroit team is actively investigating design alternatives.

Resources

- We are in the process of hiring a Mechatronics Workstream Lead to coordinate the electrical and software controls integration for the program. This is good timing in that up until now, controls integration has not been needed.

Summary and Future Work



Responses to Previous Year Reviewer‘s Comments

Comment	Response
High fuel efficiency (FE) tires will be used on this project, but there is no collaboration to improve the tires specifically for this application.	Collaboration with Michelin shown in the collaboration model, slide 4. Optimization of the tires will be for the advanced axle system which operates like a 6x2, typically showing reduced tire wear on the drive axle. Optimization will be to improve the tire life while still improving on fuel efficiency.
Reviewer questioned if the limited engine improvements on this project were sufficient payback items.	Engine technology selections attempt to balance the technology maturity (readiness level) objectives, business case requirements of the project as well as the very ambitious BTE target.
Reviewer was concerned if the funding would be sufficient to be able to compete for resources within each of the companies included in the program.	At the end of 2017, the program was slightly under budget. Each of the companies included in the program have agreed to their allocated budgets and have assigned resources to complete the work.

SuperTruck 2 Partnerships and Collaborations

US National Labs

- Oak Ridge National Laboratory
- NREL

Universities

- University of Michigan
- Clemson University

Industry

- Michelin
- Sabic
- Johnson Matthey
- Strick
- Atkinson LLC

Fleet

- Schneider